Utilizing Data from NOAA's Observing Systems to Achieve Environmental Literacy

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Abstract—**NOAA has recently significantly increased its commitment to promoting environmental literacy by adopting this effort as a strategic crosscutting priority, forming an Office of Education and Sustainable Development, and creating an Education Council. Another of NOAA's strategic crosscutting priorities is integrating global environmental observations and data management. NOAA possesses a vast array of observing systems that monitor oceanic, atmospheric, and terrestrial parameters. The streaming data from these systems offers broad opportunities to create real-time visualizations of dynamic Earth processes and to capture rare and spectacular events that occur on regional or global geographic scales. Making these visualizations available and understandable by the general public is a tall task. The potential return on investment, however, is large. By enabling the public to observe environmental processes and long-term trends occurring in their "backyards" and demonstrating the link these "backyard" processes have to global processes, we can build an environmentally literate public that makes more informed decisions. Also, it is well known that the general public has a keen interest in rare or spectacular natural events. Significant learning can occur when we can capitalize on the public's piqued interest about these phenomena. This curiosity-driven quest for information was made dramatically obvious with the Indonesian tsunami in 2004.**

NOAA's Education Council realizes the educational potential that observing system data offer and has adopted Earth Observing Systems Education as a top priority. An effort is currently underway in NOAA to assess existing observing system education activities within and outside the Agency and to pilot education programs using the available streaming data. Additionally, a new funding opportunity was announced by NOAA this spring for Environmental Literacy Grants. One of two priorities of this granting program is to support data visualization projects that utilize the data from Earth observing systems. We will report on the process of assessment and on some of the pilot projects we have begun.

Among several of the activities that NOAA has launched, the National Estuarine Research Reserve System (NERRS) provides an example of a program that provides a fully operational network of integrated observing systems that is focused on increased understanding and development of a predictive capability within the nation's estuaries. Automated dataloggers deployed within the existing NERRS generate about 33,600 measurements of estuarine water quality conditions per day (ca. 42 million measurements per year). Through its nationally distributed network of educators and its unique water quality monitoring program (System Wide Monitoring Program or SWMP), the NERRS is working to best assess how to link IOOS data streams to key user audiences. Assessing the needs of the potential user group(s) is a critical first step towards identifying the type, format, and delivery mechanisms of the data products. The NERRS, in partnership with NERRA, the Jacques Cousteau NERR, and others, plans to assess how K-12 teachers and students can use IOOS data to learn and understand the world around them including links between the ocean, atmosphere, climate and humans. We will report on the NERRS educational activities, and its plan to make its monitoring data available to different users, as well as other NOAA programs that use data for educational purposes like the Adopt a Drifter Program.

I. INTRODUCTION

There is a large and growing international movement to establish a comprehensive, integrated and sustained global Earth observation system. The basis of this system, or system of systems, would be fully shared and integrated data from existing observing systems and increased density of observations to fill critical spatial and temporal gaps in current coverage. The potential impact of such a system is great, including enhanced understanding of Earth system processes, improved resource management, reduced loss of life and property due to natural disasters, improved human health, and greater environmental literacy in the general public.

This initiative will have a dramatic impact on the organizations heavily involved in environmental monitoring. The National Oceanic and Atmospheric Administration (NOAA) has massive investments in observing systems, with over 100 different systems currently in operation measuring more than 500 environmental parameters. Not only will NOAA's vast observing systems become part of this system, but also the masses of archived environmental data and computer systems that support such data. Thus, observing systems and the data produced by such systems are a major focus of NOAA's current efforts.

One of the components of this Global Earth Observing System of Systems (GEOSS) is the Integrated Ocean Observing System (IOOS), which comprises the US coastal areas. IOOS will serve as the U.S. operational coastal observing system providing data products that will serve applied users, such as port authorities, coastal resource managers and planners, public health officials, emergency managers, and educators [1]. The White House recently designated NOAA as the lead federal agency for implementation and administration of IOOS [2]. For more information on IOOS see Larkin and Werner's paper in this issue.

II. NOAA's ENVIRONMENTAL LITERACY INITIATIVE AND OBSERVING SYSTEM DATA

A. *NOAA's Growing Education Program*

In response to stakeholder input and the recommendations in the report of the U.S. Commission on Ocean Policy [3] and the direction from the President's U.S. Ocean Action Plan [4], NOAA has recently increased its educational efforts. Promoting environmental literacy, which includes scientific understanding of Earth's processes, is a cross-cutting priority of the NOAA strategic plan, and is indicative of broad commitment to education activities within the Agency. The Office of Education and Sustainable Development (OESD) was created to coordinate education activities throughout the Agency and to guide the creation of educational programming in NOAA's mission areas that are lacking. To ensure this coordination and improve NOAA's overall education program, through policy setting and budgetary review, an internal Education Council was created with representatives from each of the line offices within NOAA and from programs that have existing education activities. NOAA's education program has also recently been enhanced through budgetary increases due to strong congressional support for these new activities.

Within the last year NOAA's Education Council identified observing system education as one of three priority areas for NOAA education. Efforts have begun internally to plan for education components associated with IOOS and, in the near future, for GEOSS.

At the same time NOAA is improving its internal organization for IOOS. The newly forming IOOS program has adopted education as one of four priority areas. NOAA's Education Council will work with the IOOS program to develop the education component for NOAA's IOOS program.

B. *Impact on Education*

The incorporation of observing system data and data products into the educational system is not an easy task. However, it would appear to be a worthy investment. Data and the data products coming from these observing systems have the potential to revolutionize the way science is learned. One of the fundamental national science education standards is science as inquiry [5]. Science as inquiry is not only a content standard, meaning a standard that a student must demonstrate a mastery of, but it is also a teaching standard. As stated in the National Research Council's National Science Education Standards [5], "All students should develop abilities necessary to do scientific inquiry and understandings about scientific inquiry. [To do so,] students must actively participate in scientific investigations, and they must actually use the cognitive and manipulative skills associated with the formulation of scientific explanations. …One challenge to teachers of science and to curriculum developers is making science investigations meaningful. Investigations should derive from questions and issues that have meaning for students. Scientific topics that have been highlighted by current events provide one source, whereas actual science- and technology-related problems provide another source of meaningful investigations." Data from observing systems can meet both of these criteria: current events (those that appear in the news) are captured and archived, as are rare and spectacular events and local events. These "hot-off-the-presses" data can be analyzed directly by students providing the opportunity for them to work with data that are relevant to where they live, related to topics they have heard about in the news, or related to a major ongoing scientific research area. And, because the data will be made available so rapidly, it allows students to make their own discoveries and pose their own scientific questions, possibly even before the scientists have had a chance to analyze the data. This immediate access to data highlights to students that not everything in science is known and well understood.

Further, because the data from these observing systems will be integrated, students will be able to make connections between processes and form an understanding of ecosystem-level impacts. Hence, observing system data is an ideal tool to teach science as inquiry. The incorporation of real and near real-time data into classroom instruction can enhance scientific literacy and build student knowledge about the environment and the dynamic and interconnected Earth processes—these are the underpinnings of environmental literacy.

C. *An Interested Public*

In addition to students and teachers, the general public and resource managers can be users of these observing systems data. The general public has an inherent curiosity about rare and spectacular environmental phenomena. Also, if the phenomenon is impacting their lives, they are highly motivated to seek information. This type of event-driven curiosity was obvious during the 2004 hurricane season when four major hurricanes struck the Florida coast in a mere three months. During this three-month period, the number of hits to the relevant NOAA websites was more than three times greater than the baseline, totaling 9 billion in July, August and September 2004 [6].

This increase in curiosity was also apparent immediately following the Indonesian tsunami in 2004. There were 25 million hits to NOAA's two tsunami warning centers in the eleven days that followed the event [6].

These dramatic increases in public access of environmental information suggests that the public is interested in this type of information and therefore supports the argument for increasing and improving access to observing system data. These pulses of acute public interest also offer an excellent opportunity to educate the public further about these events.

Even without these extreme events there is an interest within the public for regular real-time information about their local environment. A variety of NOAA programs make real-time information and data products accessible to the general public. One such program is the National Marine Sanctuary Program's interpretive weather kiosk initiative. These on-line and weather-proof kiosks are installed at public areas nearby Sanctuaries, such as harbors and science education facilities. The kiosks provide real-time connections to all locally relevant NOAA weather products, such as offshore marine forecasts, tides and currents, swell conditions, wind speed and direction, and sea surface temperatures.

In one month the online kiosk for the Channel Islands National Marine Sanctuary, off the coast of Santa Barbara, CA, receives, on average, over 61,000 hits. And for the kiosk installed at a small marine science center, there are on average 25 user sessions per day with an average length of 8 minutes each [7]. These site- and kiosk-usage statistics indicate there is interest within the general public for this real-time, local information, especially when it has direct relevance to their daily decisions, such as when to head out on a boat and where to catch the best waves.

Resource and emergency managers have a more critical need for knowledge about the same events as they need to prepare local communities for natural disasters or make decisions to mitigate future events.

D. Data are Available, But Not Easily Found

NOAA currently makes the majority of the data coming from the observing systems available in near real time. However, gaining access to these data is difficult.

One of the most ubiquitous problems with observing system data is one of access. If the users of the data don't have access to the data (access, in this case, includes actual access as well as presentation of data that are quality controlled and understandable for that particular user), then none of the benefits of these data can be realized. To enable educational uses of observing system data there are a variety of accessibility requirements, such as, the data and data products need to be easily located on an Internet site (possibly even a portal that leads to all the data), the data should be presented in a way that is understandable by a nonscientist, data sources should be integrated into useful data products (when feasible), the data should be accompanied by an explanation and samples of the types of questions scientists ask with these data, and finally the metadata should be provided. Currently, most of the sites making observing system data available do not address these requirements and thus, are not widely used in educational settings.

E. There are a Few Pioneering Education Programs

NOAA's new Adopt a Drifter Program allows K-16 grade teachers to adopt a drifting buoy and follow its trail of ocean observing data as it drifts along the ocean currents. The participating teachers are providing input to NOAA on how to construct the web site that provides the data access and they are writing lesson plans on how they are using the drifter data in their classrooms. These lesson plans will be made available on the Adopt a Drifter website. This pilot program is providing NOAA valuable information on how to create future observing system education programs. For more information on this program see Stanitski's paper in this issue.

Another education program that is pioneering the use of real and near real-time data to teach fundamental science concepts is the National Weather Service's JetSream on-line weather school. The JetSream web site contains lengthy explanations of the science behind the daily weather forecasts and provides links to that day's forecast models and near real-time data for self-directed analysis.

Finally, the National Estuarine Research Reserve System is a network of sites that is utilizing the data from an estuarine-specific "mini-IOOS" to enhance its education programs. This program will be discussed at length in the section that follows.

III. A CASE STUDY—UNDERSTANDING ESTUARIES THROUGH THE USE OF NERRS DATA

The National Estuarine Research Reserve System (NERRS) is a network of 26 protected areas established for long-term research, education and stewardship (Fig. 1). It is a partnership program between NOAA and the coastal and Great Lake states that protects more than one million acres of estuarine land and water to provide essential habitat for wildlife. The reserves offer educational opportunities for students, teachers and the public and serve as living laboratories for scientists. In each of the 26 reserves there are scientists conducting research and analyzing the data resulting from the System-Wide Monitoring Program (SWMP). NERRS stewardship coordinators and educators are engaged in K-12 programs, community education programs, and/or providing training for coastal decision-makers.

Advancing public coastal ocean literacy, which includes understanding scientific information, is one of our nation's greatest educational challenges. There is a general realization in the United States that ocean and coastal habitats are in trouble, due to stressors such as non-point source pollution and intensive land development, however, the public knows little about coastal and ocean ecology and ecosystem processes [8]. If the public poorly understands concepts and terms related to coastal management issues, then the public's understanding about the term "estuary" is also likely low. This limited knowledge about estuarine issues sets a challenge for educators and scientists working in the NERRS.

Fig. 1. Map of the U.S. showing the location of the 26 National Estuarine Research Reserves.

The first challenge is for NERRS educators to deliver effective education programs with measurable results showing an increase in estuarine literacy. The second challenge is for NERRS educators and scientists to work together in developing educational products that facilitate learning and build a deeper understanding of coastal system dynamics by integrating current knowledge of estuarine system dynamics with collected data and appropriate technology.

In order to respond to these challenges, NERRS education staff is developing unique educational products and programs that include data from the NERRS SWMP. Incorporation of these data can support inquiry- and discovery-based learning [9], and can help formulate a clearer view of the estuaries as important ecosystems.

A. The System-Wide Monitoring Program (SWMP)

The SWMP consists of a continuous 10-year data set for tracking short-term variability and long-term changes in estuarine waters. This dataset is unique in that it monitors a suite of environmental parameters at more than 120 estuarine and coastal sites nationally, providing a baseline for measuring the health of the nation's estuaries. Currently, the SWMP is in operation at all 26 reserves in the NERRS and the program has been identified as a national backbone component for IOOS due to the systems broad coverage of estuarine and coastal habitats. As component of IOOS, the NERRS is an important contributing member with extensive coastal datasets and the ability to integrate these data within education and outreach programs to enhance understanding of coastal environments and improve coastal management.

Designed as a phased monitoring program, the SWMP currently monitors abiotic water and weather parameters and has the NERRS has continued to expand the scope of the SWMP through the development and implementation of the second and third phases of system-wide data collection. The three phases of SWMP are:

Phase I. Abiotic and Biotic Monitoring including:

- Water quality parameters: pH, conductivity, temperature, dissolved oxygen, turbidity, and water level, nitrate, nitrite, ammonia, and ortho-phosphate and chlorophyll-a.
- Meteorological parameters: air temperature, wind speed and direction, relative humidity, barometric pressure, rainfall and Photosynthetic Active Radiation.

Phase II. Biological Monitoring including, habitat and estuarine population biodiversity, abundance, and distribution.

Phase III. Watershed and Land Use Classifications including, changes in land use patterns and habitat classifications.

A Yellow Springs Instrument Co. (YSI) datasonde is used to collect the water quality data in the SWMP. These datasondes collect data at 30-minute intervals. One datasonde is placed at a control site, while the other is placed at a site that is impacted by human activity and/or exemplifies a concern of the reserve (e.g., nonpoint source pollution). Two additional datasondes are placed along a gradient (i.e., either by salinity, by depth in the water column, or by differences in land use or habitat). Monthly water nutrient samples are also taken at each reserve. In addition to these YSI's, every reserve has a Campbell CR10X weather station that collects meteorological data every 15 minutes.

There are currently over 120 datasondes across the reserve system providing over 33,600 measurements of estuarine water and weather quality conditions per day (ca. 42 million measurements per year). Both the placement of the datasondes and the amount of data collected within the NERRS offers an excellent level of environmental detail that can be used for educational purposes. For example, a teacher who knows that (1) the Guana Tolomato Matanzas NERR covers two different environmental components, (2) datasondes have been set in each of these components, and (3) that one of these components is considered a pristine area, can then use this information to engage her/his students in comparing the data for the sites and have them discuss the importance of research and management of these areas.

Data collected by the reserve's monitoring program are centrally located at the Central Data Management Office (CDMO). This office oversees the management, documentation and publication of data on the Internet. The CDMO also provides Quality Assurance/Quality Control for the data, data management strategies, data protocols, and training for the reserve staff. To access the SWMP data visit nerrs.noaa.gov and click on the 'Monitoring' tab. Information about the SWMP, the parameters monitored, and information about CDMO will also be found under this section.

1) The NERR SWMP has been identified as a national backbone component of IOOS

The SWMP data will be made available on a near real-time basis in order to meet IOOS goals and additional data user needs. The NERRS SWMP monitoring stations will be connected to a telemetry system that will stream data using NOAA's Geostationary Operational Environmental Satellites (GOES). These near real-time data will be accessible as early as Fall 2005 from a subset of NERR sites, with the remaining sites' data coming online by Summer 2006. The telemetered data will be transmitted to the NERRS CDMO for near-real-time access via the Internet. The web interface and graphical forms that the data will take will be developed in close collaboration with the NERRS research, education, and management community

B. Current examples of how SWMP data are being used for educational purposes and coastal management issues

Within the last several years each reserve has had a variety of uses of SWMP data and has used a variety of delivery methods to share these data. Consistent across the reserves, however, is the goal to use SWMP data to help solve and/or mitigate real-world problems. In an educational context, the placed-based nature of the reserves, combined with the real world applicability of the SWMP data, can provide a perfect setting for engaging students in scientific inquiry [10]. Over the past several years the Reserves have generated a variety of tools that use the SMWP data to connect people and scientists in data sharing, as well as engaged people in authentic learning environments which address issues relevant to people's lives [11]. The following examples were taken from reference [12] and describe some educational applications for SWMP data.

1) Weeks Bay NERR, AL—2004 SWMP Data from Hurricane Ivan to Teach Students about the Coastal Impacts of Tropical Storms

On September 23, 2004 the Weeks Bay NERR participated in EstuaryLive, a live, online, educational program broadcast (www.estuaries.gov). Each year, educators and outreach coordinators from the NERRS and EPA's National Estuary Program (NEP) offer a program called EstuaryLive that allows students to take a live interactive field trip, in their classroom, to these exciting locations via the technology of the Internet. In 2004 a total of 13,600 students and teachers participated via the Internet, and an additional 1,000,000+ individuals had access to the program via various television stations and aquariums [13].

Unfortunately, Hurricane Ivan hit Weeks Bay on September 16th one week to the day before the NERR was scheduled to take part in EstuaryLive. The eye of the hurricane passed almost directly over the reserve, causing extensive damage. Amidst the cleanup efforts, the Weeks Bay EstuaryLive team re-wrote about 20 minutes of their 60 minute program in order to take advantage of the educational information their SWMP weather and water quality dataloggers were able to collect as the storm passed. One of their water quality dataloggers was swept away, but reserve staff prepared graphs from their intact weather and water dataloggers to teach their EstuaryLive audience in classrooms around the country what happens during a hurricane. For example, Fig. 2 shows a spike in the water level in Weeks Bay during the post-hurricane storm surge that reached almost 2 meters above mean high tide. Through the Estuary Live Weeks Bay segment, students were able to see pre- and post- storm effects, view a datalogger and its results, ask questions of a meteorology student, see sediment deposition in an actual core, on map, and on-site. Finally, hurricane data can be accessed by teachers with their classes online [13]. To see Weeks Bay NERR EstuaryLive broadcast after Hurricane Ivan, visit the archived programs on http://www.estuaries.gov

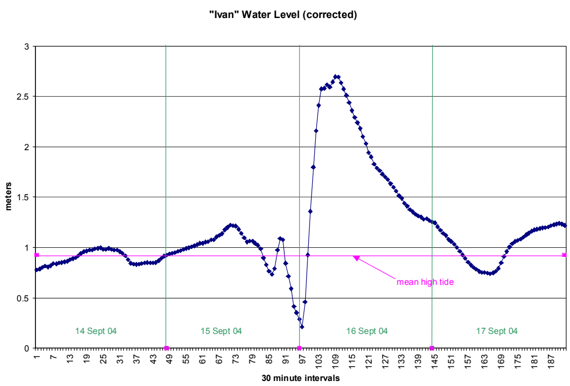

Fig. 2. Corrected water level as measured by Weeks Bay, AL NERR water datalogger over a 4-day period during which hurricane Ivan passed over the site (Sept. 16, 2004). Y-axis is meters, x-axis is time in 30-min intervals, the pink line marks the mean high tide.

2) Waquoit Bay NERR, MA—Using SWMP Data to Support Internet-Based Coastal Education Programs

Waquoit Bay NERR has developed a series of lesson plans that introduce students to the NERRS SWMP data sets. The SWMP data are used to integrate math skills with science concepts. Students can use these high-quality data sets to look at temporal patterns in temperature, salinity, dissolved oxygen, or turbidity, and can find trends over time. Students can ask and answer their own questions using the SWMP data. For example, students studying climate could find out if temperature or salinity has been increasing or decreasing over several years of sampling. Teachers can use the data to make graphs illustrating concepts such as tidal cycles or diurnal cycles in dissolved oxygen and then have their students interpret the graphs.

In order to facilitate the use of SWMP data in classrooms, Waquoit Bay NERR staff developed step-by-step instructions for downloading SWMP water quality and meteorological data from the NERRS website and translating the data into a Microsoft Excel file (http://www.waquoitbayreserve.org/pdf/access_data.pdf). The lessons guide students through the process of working with the data to create graphs and interpret the patterns and trends they reveal. These exercises give students an opportunity to work with real data from a wide range of coastal areas. The program is intended to allow teachers from a wide range of ecology and marine science disciplines to teach students about the applications of coastal monitoring data and the lessons to be learned from short-term variability and long-term trend analysis.

3) Great Bay NERR, NH – Using SWMP Data to Complete Biannual Water Quality Assessments under Section 305b of the Clean Water Act

The New Hampshire Department of Environmental Services (NHDES) uses the Great Bay NERR SWMP data extensively to assess water quality conditions. Every two years, states are required to report the status of their waters to congress under section 305b of the Clean Water Act of 1972. There are two dissolved oxygen standards used by NHDES in which SWMP data are critical. To meet NHDES standards, dissolved oxygen in a water body must not fall below 5 mg/L at any time and must have a daily mean percent saturation of at least 75%. A water body failing to meet these standards is listed as impaired in the NHDES database and becomes eligible for funding for additional studies.

The Great Bay NERR SWMP data set is unique in that it provides continuous standardized data from set locations. The continuous nature of the SWMP data allows NHDES to evaluate a water body based on data collected every thirty minutes, every day, under changing weather conditions and seasons. The NERR SWMP is currently the only source of information of its kind available to an agency like NHDES for use in the 305b reporting process in collaboration with the Environmental Protection Agency's (EPA).

4) Hudson River NERR, NY—"Swamping the Classroom" - Pilot Program Designed to Help Educators use SWMP Monitoring Data in Science Curricula

Reserves like the one located along the Hudson River, NY are developing and testing educational products that incorporate the use of SWMP data with local relevance and applicability through a program currently called "Swamping the Classroom". This is a web-based education program that fosters an awareness of the Hudson River Estuary within its watershed. A pilot version under development in the spring of 2006 will link middle-school science classes in the mid-Hudson Valley with 12 years of water quality monitoring data from five tributaries of the Hudson River spanning the middle hundred miles of the 153 mile-long Hudson River Estuary. These data have been collected by the Hudson River NERR at its four separate reserve sites as part of SWMP.

"Swamping the Classroom" will include learning modules, pre-selected data sets, watershed maps, aerial photographs and links to related websites and videos. It will be housed on Blackboard, a web-based education platform, and accessed through Ulster County BOCES (Board of Cooperative Educational Services), a county-level network in New York State.

If the pilot proves successful, "Swamping the Classroom" will consider expanding its scope in the following dimensions:

- A wider geographical audience, to reach classrooms in all of the counties adjacent to the Hudson River Research Reserve sites.
- A larger curricular audience, including high school level science classes.
- Closer links to related Hudson River educational programs, such as Hudson Basin River Watch, which supports water quality monitoring of Hudson River tributaries by volunteer community groups (many of them school-based).
- Expanded links to the NERRS SWMP, allowing students in the Hudson Valley to compare and contrast different estuarine systems around the United States.

C. Generating smart tools for decision-making and authentic learning – NERRS' future workplan

The SWMP has powerful educational potential because of the variety of environmental parameters that are continuously monitored, as well as the stories that can be developed by integrating three different types of data (abiotic, biological, watershed and land use). Ecosystem-level processes and the interconnected nature of watersheds can become obvious through well developed data visualizations. As can be seen from the previous examples, NERRS educators are seeking different ways and tools to incorporate SWMP data into educational programs and products as a way to stimulate curiosity, promote inquiry based programs, connect with local scientists, and, especially, to support learners in developing a more sophisticated understanding of estuarine and coastal systems. Reserve staff will continue to explore the application of new technologies for the development of a national educational program that incorporates the SWMP data.

1) New website improving access to SWMP data

An updated website has been recently launched by CDMO (http://cdmo.baruch.sc.edu) that will give the user flexibility to select the specific SWMP data they wish to query and how they would like to see the data presented. Users can graph, export and generate statistics on the queried data as well as link to the associated metadata using the Query Data link. SWMP data users will now be able to manipulate the data to help them interpret trends in dissolved oxygen saturation levels and facilitate their understanding of how fish kills and algal blooms occur, as well as understand distribution and abundance patterns of submerged aquatic vegetation. Students can query the data and look for evidence of water quality degradation caused by runoff or hurricane impacts. Such an exercise will give students practice working with graphs and technology within a meaningful and engaging context. Coastal managers can also use these monitoring data to make informed decisions on local and regional coastal zone issues, such as public health concerns, point and non-point source pollution policies, and the success of restoration projects.

The NERRS and CDMO will continue to work and improve the functionality of the website. In the near future it is expected that it will allow for cross querying between reserves and years. It will also incorporate Geographical Information Systems (GIS) maps into the website with more advanced graphing capabilities.

The NERRS has also considered the need to have web interfaces developed for specific user groups, as well as data visualization tools or models developed to help users interpret the data. From an education perspective, visualization tools should make science accessible, provide means for additional inquiry based research, and lay the groundwork to understand and critique scientific issues [14]. The reality of student learning and coastal decision-making is, however, often far removed from theoretical perspectives. In educational settings, researchers have found that, unlike most scientists, students are often unfamiliar with how to effectively use and interpret diagrams and other visual aids [14]. NERRS educators will be working to address these limitations, recognizing that teachers should not have to be data-access technicians, and realizing that there needs to be a better understanding of how learners of all ages acquire and refine estuarine concepts over time. This type of information will help define the type of visualization tools or use of appropriate technologies required to assist with SWMP data interpretation.

2) Assessing the education community needs for NOAA/NERRS SWMP data

At this point, the NERRS is only beginning to achieve a working understanding of the different data user needs, the types of tools that would be most appropriate for the different users, and how improved SWMP data access would impact Earth system education at all levels. A needs assessment will be conducted, of the interests and needs of educators at all levels for NOAA-related scientific data sets. This assessment will be conducted by the Jacques Cousteau NERR, NOAA's Estuarine Reserves Division and the National Estuarine Research Reserve Association (NERRA) with the support of OESD. The goal is to develop a strategic plan, in collaboration with NOAA's National Marine Sanctuary Program, National Sea Grant College Program and the

Centers for Ocean Science Excellence in Education (COSEE), to determine best practices for how K-12 teachers and students can use IOOS data. Specific objectives of this project include: (1) assessing the availability of IOOS data streams that could be of use to the K–12 community; (2) determining NOAA partners (e.g., NERRS, Sea Grant, etc.) views of their ideal use of IOOS data streams in K–12 classrooms; (3) assessing K–12 teachers' capabilities, needs, interests, and concerns about using NERRS-IOOS data; and (4) conducting a gap analysis between NOAA partners and audience needs. Workshops are planned for the fall of 2005 and the winter of 2006.

This assessment will also play an important role in shaping the development of the national NERRS education. Such an expanded program might include improving teacher and student competencies required for data manipulation, data analysis and interpretation, understanding the range of spatial and temporal scales that link coastal processes, and understanding the multifaceted (dynamic, chemical, biological, ecological) way in which components of the Earth and human systems are connected. The NERRS education program goals and products will also be, applicable across the Science, Technology, Engineering and Mathematics (STEM) disciplines.

IV. FUTURE DIRECTIONS AND TACKLING CHALLENGES

A. Challenges of the K-12 environment

In recent teacher workshop evaluations conducted by the National Marine Sanctuary Program, some of the challenges associated with bringing real data into the classroom became apparent.

Overwhelmingly, most K-12 teachers think primarily of marine animals and their habitats when they think about incorporating ocean science topics into their curriculum. When these teachers were asked to select the types of information the Sanctuaries Program could provide to supplement their curriculum, live video imagery from the ocean consistently outranked several real-time ocean and weather data options. These responses highlight the need to demonstrate how ocean observing data are relevant to the core science subjects and standards they are required to teach and, to exploit their interest, how marine animals and habits are inextricably linked to the factors being observed by the observing system. Because ocean science topics are largely absent from the national and state science education standards, teachers do not automatically cover ocean concepts in their curriculum.

Fortunately, these evaluations also showed that teachers had a greater interest in using real-time ocean and weather data in their classrooms after they had participated in a Sanctuary workshop. These results indicate that observing system education products will need to be accompanied by teacher professional development workshops to demonstrate how these products can be used in classroom instruction. Furthermore, teachers indicated that they primarily seek lesson plans when visiting web sites like the National Marine Sanctuaries rather than streaming data. Again, this is indicative of the need to incorporate observing system data into well-developed lesson plans for teachers and offer workshops to demonstrate their use.

Finally, there exists a large challenge associated with creating useful observing system data visualization products for education. Not only are the technical limitations on what types of software and Internet access teachers have in their classrooms, but there is currently insufficient information available on the types of visualizations that are truly educationally effective [15].

B. Facilitating Observing System Data Access and Providing Education Products

To address these and other challenges, NOAA's education program is working to facilitate the effective use of ocean, coastal, estuarine, and atmospheric science data, visualizations, and models by the education community. To accomplish this, a number of activities are underway or planned:

- Conduct a needs assessment of educators (described in NERRS section)
- Identify best practices in using data to teach science
- Identify components of IOOS, and later other observing systems, that are currently readily adaptable for use in an education setting
- Work with the data management and communications (DMAC) to incorporate education user requirements
- Identify and adopt best practices in data visualization techniques used for education
- Support pilot projects that demonstrate best practices and meet the needs of educators
- Create education products that utilize integrated data streams coming from a variety of observing systems so that concepts such as ecosystem functioning and management and Earth system processes can be taught using real and current data
- Develop teacher professional development workshops to demonstrate how to use observing system data in the classroom
- Adopt the newly developed seven essential principles of ocean science as an organizational element for ocean-related education products (See Schoedinger, Cava, Strang and Tuddenham's paper in this issue for more on the Ocean Literacy Initiative)

V. CONCLUSION

Building environmental literacy through the use of Earth observing system data is possible, however, it will be a challenge. NOAA has accepted this challenge, and through collaboration with its partners, will work to build internal capability to deliver observing system data educational products that assist teachers in meeting education standards, highlight current environmental issues, and allow the general public and other decision makers access to these real-time data. By enabling the public to observe environmental processes and long-term trends occurring in their "backyards" and demonstrating the link these "backyard" processes have to global processes, we can build an environmentally literate public that makes more informed decisions.

VI. FOR MORE RESOURCES

- NOAA Office of Education and Sustainable Development: http://www.oesd.noaa.gov/
- NOAA/National Estuarine Research Reserve System: http://nerrs.noaa.gov
- Central Data Management Office (CDMO) (http://cdmo.baruch.sc.edu)
- Estuaries Lesson Plans using SWMP data http://oceanservice.noaa.gov/education/kits/estuaries/welcome.html
- NOAA's Geostationary Satellites (GOES): http://www.nesdis.noaa.gov/satellites.html
- NWS National Digital Forecast Database www.nws.noaa.gov/ndfd/
- NOAA's National Data Buoy Center http://www.ndbc.noaa.gov
- Creating Structure and a New Vision for NOAA's Observing Systems – 2005 Article: http://www.magazine.noaa.gov/stories/mag163.htm
- NOAA's Satellites and Information: http://www.nesdis.noaa.gov/outreach_edu.html
- The COOL (Coastal Ocean Observation Laboratory) Classroom http://www.coolclassroom.org/home.html
- National Office for Integrated and Sustained Ocean Observations: http://ocean.us/
- Ocean Literacy: The Essential Principles of Ocean Sciences K-12 http://www.coexploration.org/oceanliteracy

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